Incidence, magnitude, and predictors of shortening in young femoral neck fractures

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Abstract: OBJECTIVES: To describe the incidence and magnitude of femoral neck fracture shortening in patients age younger than 60 years. Secondarily, to examine predictors of fracture shortening. DESIGN: Retrospective chart review. SETTING: Level I trauma centre. PATIENTS/PARTICIPANTS: Sixty-five patients with a median age of 51 years (interquartile range: 42-56 years) were included. Seventy-one percent were male, 75% were displaced fractures, and 78% were treated with cancellous screws. INTERVENTION: Internal fixation with multiple cancellous screws or sliding hip screw (SHS) + derotation screw. MAIN OUTCOME MEASUREMENTS: Radiographic femoral neck shortening at a minimum of 6 weeks after fixation. RESULTS: Fifty-four percent of patients had 5 mm of femoral neck shortening (22% had between 5 and <10 mm and 32% 10 mm). Initially, displaced fractures shortened more than undisplaced fractures (mean: 8.1 vs. 2.2 mm, $P < 0.001$), and fractures treated with SHS + derotation screw shortened more than fractures with cancellous screws alone (10.7 vs. 5.5 mm, $P = 0.03$). Even when adjusting for initial fracture displacement, fractures treated with SHS + derotation screw shortened an average of 2.2 mm more than fractures treated with screws alone ($P = 0.03$). CONCLUSIONS: The incidence of clinically significant shortening in our young femoral neck fracture population was higher than anticipated, and 32% of patients experienced severe shortening of >1 cm. Our findings highlight the need for further research to determine the impact of severe shortening on functional outcome and to determine if implant selection affects fracture shortening. LEVEL OF EVIDENCE: Prognostic Level IV. See Instructions for Authors for a complete description of levels of evidence.

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Incidence, Magnitude, and Predictors of Shortening in Young Femoral Neck Fractures

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Objectives: To describe the incidence and magnitude of femoral neck fracture shortening in patients age younger than 60 years. Secondarily, to examine predictors of fracture shortening.

Design: Retrospective chart review.

Setting: Level I trauma centre.

Patients/Participants: Sixty-five patients with a median age of 51 years (interquartile range: 42–56 years) were included. Seventy-one percent were male, 75% were displaced fractures, and 78% were treated with cancellous screws.

Intervention: Internal fixation with multiple cancellous screws or sliding hip screw (SHS) + derotation screw.

Main Outcome Measurements: Radiographic femoral neck shortening at a minimum of 6 weeks after fixation.

Results: Fifty-four percent of patients had ≥5 mm of femoral neck shortening (22% had between ≥5 and <10 mm and 32% ≥10 mm). Initially, displaced fractures shortened more than undisplaced fractures (mean: 8.1 vs. 2.2 mm, $P < 0.001$), and fractures treated with SHS + derotation screw shortened more than fractures with cancellous screws alone (10.7 vs. 5.5 mm, $P = 0.03$). Even when adjusting for initial fracture displacement, fractures treated with SHS + derotation screw shortened an average of 2.2 mm more than fractures treated with screws alone ($P = 0.03$).

Conclusions: The incidence of clinically significant shortening in our young femoral neck fracture population was higher than anticipated, and 32% of patients experienced severe shortening of >1 cm. Our findings highlight the need for further research to determine the impact of severe shortening on functional outcome and to determine if implant selection affects fracture shortening.

Key Words: femoral neck fracture, adult, fracture shortening, incidence, internal fixation, trauma

Level of Evidence: Prognostic Level IV. See Instructions for Authors for a complete description of levels of evidence.

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INTRODUCTION

Fractures of the femoral neck in patients younger than 60 years are distinctly different from those sustained by elderly individuals. They are less common, they occur from higher energy trauma, and they are associated with frequent complications.[1] Operative fixation of young femoral neck fractures is indicated to restore function and preserve the native hip joint.[2] The most commonly used fixation implants are multiple cancellous screws or a sliding hip screw (SHS).[3,4] The sliding nature of these constructs promotes healing through compression of the fragments; however, excessive shortening may lead to poor functional outcomes. At least 2 previous studies have demonstrated negative associations between fracture shortening greater than 5 mm and quality of life.[5,6] In addition, it is known that in the geriatric hip fracture population, the incidence of significant shortening is as high as 66%.[6]

The incidence and magnitude of fracture shortening in young adult femoral neck fracture patients is relatively unknown. The purpose of this study is to describe the incidence and magnitude of shortening in young femoral neck fractures after fixation with cancellous screws or an SHS. We hypothesized that some shortening would be common in this population but that severe fracture shortening would be relatively rare. Our secondary objective was to identify patient, injury, and treatment variables associated with fracture shortening.

PATIENTS AND METHODS

On approval from the University of British Columbia's Clinical Research Ethics Board, we conducted a search of our prospectively maintained orthopaedic trauma database to

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identify young adult femoral neck fracture patients treated at our Level I trauma center. Participants were eligible if they (1) were age 18–60 years, (2) sustained a femoral neck fracture between January 2003 and May 2013, (3) were treated with closed or open reduction and surgical fixation with either multiple cancellous screws or an SHS, (4) had appropriate radiographs (standard anteroposterior and lateral) taken both in surgery and at last follow-up, and (5) had at least 6 weeks (42 days) of follow-up. This minimum follow-up was accepted recognizing that the results obtained may possibly underestimate the true final amount of fracture shortening. Participants were excluded if they (1) were treated with arthroplasty or cephalomedullary nail, (2) had a disorder of bone metabolism that could affect fracture healing, (3) had a pathologic fracture, or (4) sustained a trauma that required ipsilateral femoral shaft fixation. Polytrauma patients were only excluded if concomitant injuries affected the management of the femoral neck fracture. Patient demographic and operative data were collected including age, gender, mechanism of injury, social history (smoking or alcohol abuse), and method of reduction.

Fracture Management

Five fellowship-trained orthopaedic traumatologists managed all fractures. All treatment decisions were made at the discretion of the attending surgeon. At our institution, most young femoral neck fractures receive operative fixation within 12 hours of injury and are reduced with closed techniques. Postoperatively, all patients are kept non-weight bearing for at least 6 weeks after surgery. In patients where radiographic and clinical healing appear to be progressing toward union at 6 weeks, weight bearing is advanced slowly from toe touch to weight bearing as tolerated over the subsequent 6 weeks. The decision of how quickly to advance a patient's weight bearing status after the first 6 weeks is at the discretion of the treating surgeon. This postoperative protocol is followed regardless of the reduction or fixation techniques used.

Radiographic Measurements

The primary outcome of the study was radiographic femoral neck shortening at a minimum of 6 weeks after fixation. All injury x-rays were reviewed to determine the fracture classification (Garden,[7] Pauwels,[8] and OTA[9]), level of fracture, and fracture displacement. Intraoperative and early postoperative radiographs were used to assess the quality of reduction and, when necessary, confirm any remaining characteristics of the fracture pattern. Fracture displacement was categorized based on the Garden classification: undisplaced (Garden I and II) or displaced (Garden III and IV). Fractures were considered to have a radiographic anatomic reduction when there was no evidence of residual displacement or angular deformity in any plane. Shortening was measured along the long axis of the femoral neck using the intraoperative or immediate postoperative film and the last available follow-up radiograph. In cases of fixation using parallel screws, shortening was measured using the screw with the greatest amount of lateral protuberance in the follow-up radiographs compared with initial fixation. For SHS devices, shortening was measured by the amount of lateral protuberance of the derotation screw. There were no cases of a single screw demonstrating protuberance without some shortening in the adjacent screws. All radiographs were adjusted for magnification using the ratio of the radiographic screw diameter divided by the known screw diameter. In the cases where screw diameter was not known, it was estimated to be 6.5 mm (instead of 7.3 mm) because this would provide a smaller estimate of shortening and effectively bias the results toward the null hypothesis. Post hoc sensitivity analysis determined that differences in screw diameter could potentially underestimate the average fracture shortening by less than 0.8 mm. A single author (D.J.S.) performed all shortening measurements for the data analysis. An additional author repeated all measurements (G.O.) to determine the reliability of our measurement technique, and interrater reliability was assessed using the intraclass correlation coefficient (ICC 2,1).

Data Analysis

Descriptive statistics were performed for all study variables. Counts and proportions were used for nominal data, and the mean ± SD or the median with interquartile range (IQR) was used for continuous data depending on its distribution. Univariate analysis was performed to identify potential predictors of fracture shortening. Forward and backward stepwise linear regression models were developed to independently adjust for significant variables identified in the univariate analysis ($P < 0.2$ for eligibility). Significance was set at $P < 0.05$ for all final analyses. Statistical testing was performed using JMP 9 software by SAS (Cary, NC).

RESULTS

Sixty-five patients met the eligibility criteria between January 2003 and May 2013 (see **Figure**, **Supplemental Digital Content 1**, http://links.lww.com/BOT/A394). Patient demographics and the distribution of fracture patterns are summarized in Table 1. Briefly, the median age of included subjects was 51 years (IQR: 42–56 years) and 71% of participants were male. One-third of all injuries occurred from a high-energy mechanism such as a motor vehicle accident or pedestrian struck by a vehicle.

Seventy-five percent of the femoral neck fractures were displaced (Garden III or IV) and 35% had a vertical fracture line (Pauwels Type III). Closed reduction was performed in 85% of cases. Seventy-eight percent of cases were treated with multiple cancellous screws in an inverted triangle, regular triangle, or diamond pattern. The remaining cases were treated with an SHS + cancellous derotation screw. Anatomic radiographic reduction was achieved in 61% of cases. The median length of follow-up was 222 days after fixation (IQR: 101–399 days).

Fifty-four percent of patients had ≥5 mm of femoral neck shortening: 22% between ≥5 and <10 mm and 32% ≥10 mm (Table 2). Overall, the median amount of radiographic femoral neck shortening was 5.8 mm (IQR: 0–11.7 mm). The interrater reliability of the shortening measurements was near perfect [intraclass correlation coefficient = 0.968 (95% confidence interval, 0.947–0.981)]. Univariate analysis for predictors of femoral neck shortening revealed

TABLE 1. Patient Demographics and Fracture Classification

Patient Demographics					
Median age (IQR), y					51 (42–56)
Male					46/65 (71%)
High-energy MOI*					21/65 (33%)
Smoker					19/65 (29%)
History of alcohol abuse					11/65 (17%)
Garden Classification		**Pauwels Classification**		**OTA Classification**	
Garden I	7/65 (11%)	Pauwels I	4/65 (6%)	31-B1	7/65 (11%)
Garden II	8/65 (12%)	Pauwels II	37/65 (57%)	31-B2	37/65 (57%)
Garden III	41/65 (63%)	Pauwels III	23/65 (35%)	31-B3	20/65 (31%)
Garden IV	8/65 (12%)				

*High-energy mechanism of injury: fall >1 m, motor vehicle accident, or pedestrian/bicyclist struck.

significant associations with initial fracture displacement and fixation implant. Displaced fractures shortened more than nondisplaced fractures (mean: 8.1 vs. 2.2 mm, $P < 0.001$). Similarly, fractures treated with SHS + derotation screw shortened more than fractures fixed with multiple cancellous screws alone (10.7 vs. 5.5 mm, $P = 0.03$). There were no significant associations between the implant selected and several important fracture characteristics, including fracture displacement, Pauwels angle, Pauwels classification, Garden classification, or level of fracture ($P > 0.05$). Finally, no other associations between fracture shortening and patient or injury variables were detected.

Regression analysis confirmed the independent associations of initial fracture displacement and fixation type on femoral neck shortening (adjusted $R^2 = 0.17$, $P < 0.001$) and failed to include any additional significant predictors. When adjusting for initial fracture displacement, fractures treated with an SHS + derotation screw shortened an average of 2.2 mm more than fractures treated with cannulated screws alone ($P = 0.03$).

DISCUSSION

In our series of 65 nongeriatric femoral neck fractures, we found the incidence of fracture shortening ≥5 mm to be 54%. Although we expected a high incidence of mild shortening, we were surprised that 32% of patients shortened greater than 1 cm. Figures 1–3 provide an example of severe shortening. In addition, the increased shortening associated with SHSs also contradicted our expectations, and the interpretation of our study results requires further discussion.

Fracture shortening after internal fixation of young adult femoral neck fractures remains poorly described. Huang et al[10] reported a 17% incidence of femoral neck shortening >5 mm in their series of 146 patients ages younger than 60 years; however, all fractures were treated with multiple cancellous screws. Pollak et al[11] noted a 4.7% incidence of malunion in their series of 86 nongeriatric patients. Finally, Zlowodzki et al[6] reported a high incidence of shortening in elderly patients, with mild shortening (<5 mm) in 34% of cases, moderate (5–10 mm) in 36% of cases, and severe (>10 mm) in 30% of cases. Our study extends these early reports by carefully describing the distribution of shortening in our younger population and identifying potentially associated predictors.

TABLE 2. Femoral Neck Fracture Shortening

<5 mm	30/65 (46%)
≥5 and <10 mm	14/65 (22%)
≥10 mm	21/65 (32%)

The technical challenges and fracture healing complications associated with this fracture are well described[12]; however, the functional significance of fracture shortening appears to be emerging in the literature. In the series by Pollak et al,[11] malunion was associated with a 12-point reduction in the physical component summary score of the Short Form-36. In geriatric patients, shortening >10 mm had significantly lower SF-36 physical functioning scores compared with patients with <5 mm of shortening.[6] Decreasing the abductor moment arm has well-documented negative functional effects in the hip arthroplasty literature[13,14] and it is reasonable to expect that the potentially negative impact of femoral neck shortening may be magnified in younger more active populations.

The association between initial fracture displacement and increased femoral neck shortening is not surprising. A recent study of fracture morphology in a series of young adult femoral neck fractures identified posteroinferior femoral neck comminution as an important determinant of the fracture stability.[15] This observation is consistent with our finding that displacement (and likely comminution) leads to more shortening. Similarly, Huang et al[10] detected an increased incidence of shortening ≥5 mm among displaced young adult femoral neck fractures with posterior cortex disruption than among nondisplaced fractures. Because the proportion of displaced femoral neck fractures in our series was similar to the pooled results of a recent meta-analysis,[12] we suspect that the incidence of fracture shortening in most young femoral neck populations is high and primarily unreported.

The association between treatment with an SHS and increased fracture shortening was the most interesting

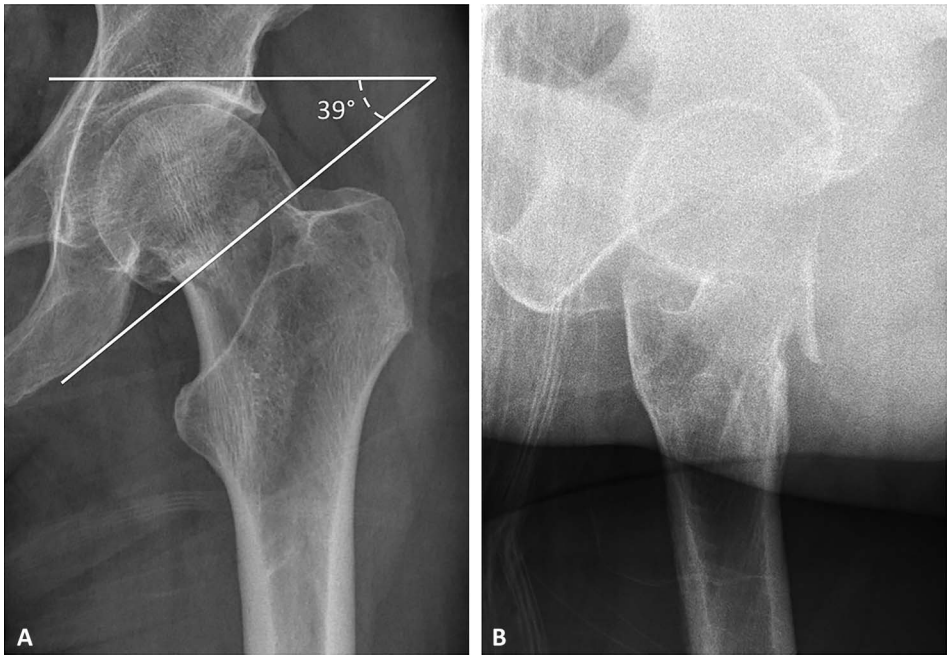

FIGURE 1. Anteroposterior (A) and lateral (B) radiographs of a Pauwels II femoral neck fracture in a 52-year-old man after low-energy trauma (a fall from <3 feet).

predictor identified. Controversy exists when choosing the optimal fixation implant for young femoral neck fractures; however, recent retrospective studies have shown substantially decreased reoperation rates with an SHS compared with multiple cancellous screws.[16,17] Proponents of the SHS argue that cancellous screws fail from bending or shear forces that result from the vertical fracture pattern more frequently seen in the nongeriatric population. Conversely, traditional proponents of multiple cancellous screws advocate for the construct's superior torsional stability, limited disruption of femoral head blood supply, and retention of more viable bone than the larger SHS.[18–21] Our results identified that the SHS was associated with more shortening than multiple cancellous screws, even when adjusted for initial fracture displacement. However, we are extremely cautious in our interpretation of this result because of the small number of cases treated with an SHS and the high likelihood of selection bias within more unstable fractures. Anecdotally, we believe that there were inherent differences in the fracture patterns that caused surgeons to select the SHS + derotation screw instead of the more typical cancellous screw construct used at our institution. Ultimately, the most difficult fractures may have preferentially received the fixed-angle SHS.

The primary limitation of the current data is the retrospective nonrandomized study design. The proportion of fractures treated with SHS (14/65) may have limited our ability to detect significant associations. We believe that treatment with SHS is associated with more severe fracture

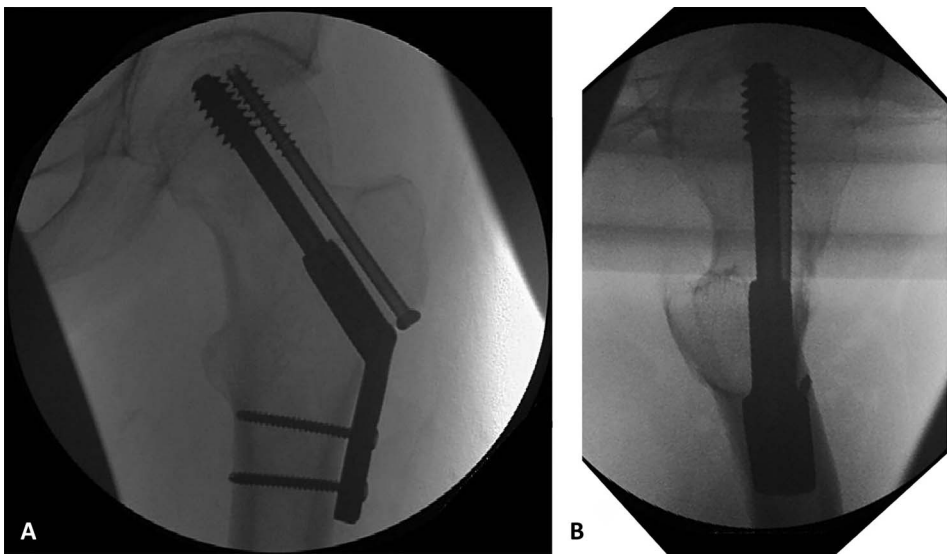

FIGURE 2. Anteroposterior (A) and lateral (B) intraoperative fluoroscopy showing closed reduction and internal fixation with SHS and 7.3-mm-diameter derotation screw.

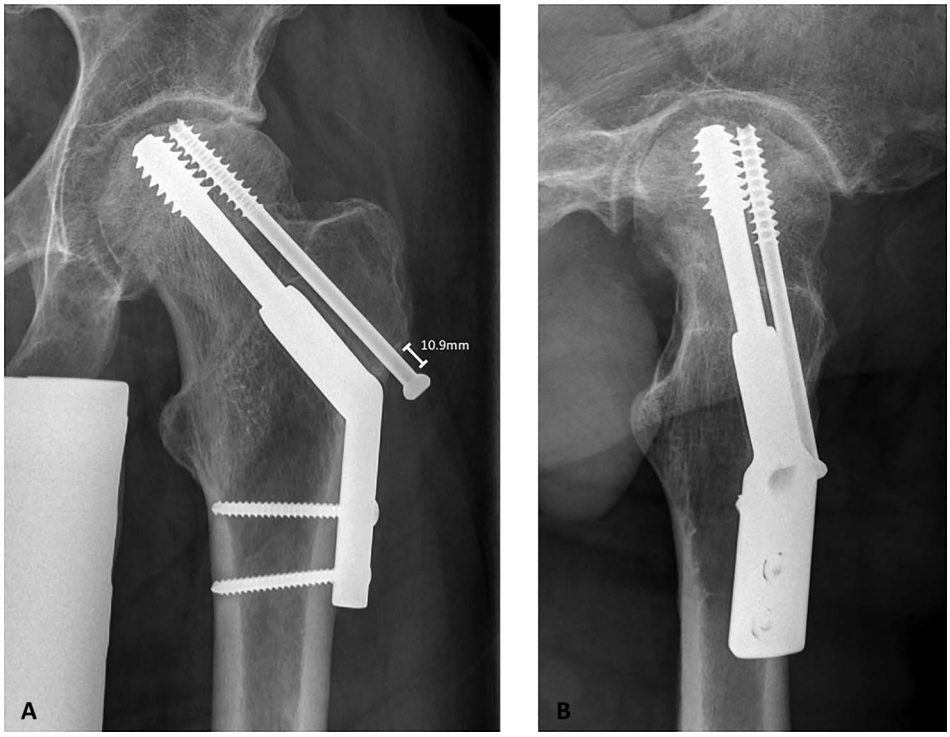

FIGURE 3. Anteroposterior (A) and lateral (B) radiographs at 18 months of follow-up showing 10.9 mm shortening. Of note, this patient concomitantly developed avascular necrosis of the femoral head.

pattern but that our study was underpowered in detecting this. Another important factor to consider in our study design is the minimum necessary follow-up was 6 weeks. Although this early time point is sufficient for assessing shortening, we are unable to comment on other important outcomes such as avascular necrosis, nonunion, or reoperation. We recognize that with a minimum study follow-up of 6 weeks, this could significantly underestimate the actual amount of shortening that occurs; however, it is important to note that 75% of the patients actually had follow-up of greater than 3 months and the median follow-up was over 7 months. This suggests that most fractures were likely followed to union.

The strengths of our study include the ability to identify a consecutive series of patients through our prospectively collected fracture database and the number of patients included in our analysis. Our method of determining fracture shortening is simple and reproducible. We believe that other methods of measuring shortening using the contralateral hip are also valid but may be more suited for the prospective research environment where leg rotation can be standardized; regardless, both methods are equally susceptible to the apparent effects of leg rotation. Other strengths include using a linear regression model to adjust for fracture displacement when comparing the effect of the treatment decision.

The potential clinical relevance of our findings is important. This study has reported more than half of our series of young adult patients with femoral neck fractures experienced shortening $\geq$5 mm and almost one-third experienced severe shortening $\geq$10 mm. Emerging literature suggests that these magnitudes of shortening are associated with clinically important decreases in functional outcomes. Our findings also emphasize the need for further research that prospectively evaluates the interactions between initial fracture pattern, implant chosen, subsequent shortening, and importantly, functional outcome. The high incidence of avascular necrosis, nonunion, and reoperation previously reported in the literature, combined with the alarmingly high rate of potentially significant fracture shortening in our current series, highlights the need for increased research efforts to improve the care of these challenging fractures.

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